Advanced Research in Conservation Science

Journal homepage: https://arcs.journals.ekb.eg

DOI: 10.21608/arcs.2022.131062.1022

# Preliminary Study for the Evaluation of Basil Essential Oil in the Preservation of *Ficus sycomorus* Wood

**Lenda Sharaf[a*], Nesrin M. N. El Hadidi[b], WesamEldin I. A. Saber[c]**

a. MA student, Conservation Department, Faculty of Archeology, Cairo University, Giza, Egypt.
b. Conservation Department, Faculty of Archeology, Cairo University, Giza, Egypt (nelhadidi@cu.edu.eg).
c. Microbiology Department, Research Institute of Soils, Water and Environment, Agricultural Research Center, Giza, Egypt (wesameldin.saber@arc.sci.eg)

## HIGHLIGHTS

- *Aspergillus spp.*, especially *Aspergillus niger* is the most commonly identified fungi in wooden artifacts.
- Essential oils are an eco-friendly treatment applied for the protection of wooden artifacts.
- FTIR spectroscopy, pH value and color change measurements were applied to assess the effect of basil oil on wood.

## GRAPHICAL ABSTRACT


## ARTICLE INFO

**Article History:**
**Received:** 2 April 2022.
**Revised:** 10 May 2022.
**Accepted:** 14 June 2022.
**Available online:** 25 June 2022.

**Keywords:**
Basil essential oil, Sycamore wood, FTIR, *Aspergillus spp*.

## ABSTRACT

Essential oils are used for multiple purposes in different fields; and recently they became vital in the conservation field. Basil oil, one of many essential oils, is known for its fungicidal activity against fungi, which attacks organic materials, such as wood. Throughout the ages sycamore fig wood, which is native in Egypt, was commonly used in archaeological artifacts; yet due to its hygroscopic properties it is usually infested with microorganisms, especially *Aspergillus sp.* To sustain wooden cultural heritage, it is necessary to

*** Corresponding author: lendasharaf00@gmail.com**

protect it from fungal attack using an environmentally friendly material, which is safe for both the object and conservator.
As a preliminary step microbiological studies were carried out on a wooden sycamore mask to identify the microbial infestation. This was followed by an experimental study, which aimed to study the effect of basil oil treatment on sycamore wood samples. Heat ageing process was carried out on naturally aged wood to simulate archaeological samples; and for evaluation and assessment of oil treatment FTIR analysis, color change measurements and pH value were carried out. The obtained results suggest that basil oil plays a role in protecting wood not only from microbial infestation, but also from ageing, and reduces the alkalinity of wood directly after treatment. The ratio between lignin/carbohydrates (hemicellulose, crystallized and amorphous cellulose) was not totally affected in the treated samples after heat ageing when compared to the untreated aged samples. Therefore, it is strongly recommended to introduce basil oil as an effective environmentally friendly material in preventive conservation treatments.

## 1. Introduction

Anatomical structure and chemical composition varies according to species, and accordingly the intensity of a microbial infestation varies. *Ficus sycomorus* is a porous low density wood, with a specific gravity of 0.47; the radial diameter of the vessel cells in various sycamore species ranges between 117-176 µm and the vessel frequency ranges between 4 – 13/ mm$^2$ [1]. Quantitative chemical analysis in previous research showed that this wood is composed of 30% lignin and 39% carbohydrates [2].
Archaeological wood in Egypt is often found infested with microorganisms, especially fungal species such as *Aspergillus* spp., *Alternaria alternata*, *Cladosporium* sp. and *Penicillium* sp. In previous studies, these species of fungi and many other species have been identified [3], and their degrading effect on wood has been discussed [4] [5]. Therefore, researchers are continuously developing methods for the protection of wood against fungal decay, and the efficacy of many fungicides has been assessed, but not all chemical fungicides are suitable for indoor applications, because of their health hazards. Natural solutions are environmentally-friendly, and they include plant extracts such as essential oils, which are known for their antifungal and antibacterial activities. The essential oil of basil (*Ocimum basilicum*) has antifungal activity against *Aspergillus* spp. [6][7], and thus, has been recommended for use, because it is easily available, and has an anti-decay action that makes it applicable as a wood preserver [8]. A main concern in the field of archaeological wood conservation is the adverse effect of any treatment on the wood itself, therefore, this study aims to evaluate the effect of the essential oil of *O. basilicum* on the chemical and physical properties of sycamore wood, an angiosperm, which was commonly found in ancient Egyptian artifacts and is commonly infested with microorganisms.

## 2. Materials and Methods

### 2.1. Archaeological samples

***The wooden mask***

As a starting point for this study a wooden face mask of unknown origin, currently stored in the Herbarium, Botany Department, Faculty of Science - Cairo University was documented and investigated. The wooden face mask, which was originally designed in ancient Egypt to resemble the face of a deceased person in order to help for the soul to recognize it according to ancient beliefs, was carved out of *Ficus sycomorus* wood, as previously identified by El Hadidi [2]. This type of wood was commonly used in carving wooden masks in ancient Egypt and is often found to be in a fragile condition [9], probably due to its low density and high porosity, as aforementioned.
Fungal studies of wooden samples were conducted in the Tag Elezz Research Station, Soils, Water and Environment Research Institute, Agricultural Research Center Dakahlia, Egypt.

## 2.2. Isolation of fungi

The technique of swab sampling was used by passing sterilized cotton swabs over seven different parts of the wooden mask as in (Table 1). The samples were cultivated on plates of potato dextrose agar (PDA) medium, composed of 200 g of potato starch, 20 g of dextrose, 20 g of agar and 1000 ml distilled water, then sterilized at 121°C for 15 min. For up to 7 days of incubation at room temperature the plates were mainly investigated on a daily basis for *Aspergillus spp*., which is one of the most commonly identified species in archaeological samples in Egypt.

## 2.3. Experimental samples

Rectangular chips (1.5 ×3 ×0.5 cm) of *Ficus sycomorus* were prepared. A hole was drilled in the center of each of the wood chips' samples so that they would hang freely during the exposure to the vapor of basil oil. For pH measurements and FTIR analysis sawdust samples were prepared.

The samples (chips and sawdust) were given the following codes; control sample (S1), samples exposed to essential oil vapor (S2 and S3).

## 2.4. Accelerated heat ageing method

The experimental study was based on samples of *Ficus sycomorus* wood (the same type of wood identified in the mask), that had been exposed to a natural ageing process for twenty years. For further ageing, to simulate archaeological wood, the samples were thermally aged at (100 ± 5˚C) for 40 hours in an oven (Heraeus, JTC- 905) at the Conservation Department - Faculty of Archaeology - Cairo University. It is very difficult to reach a state of deterioration similar to that badly infested wood, such as that of the mask, but color change measurements and FTIR spectra indicated that the wood was slightly similar to archaeological wood (Fg. 1).

To compare the effect of the basil oil on the wood directly after treatment and after exposure to heat ageing, the wood treated with the vapor of the essential oil was exposed to a second artificial ageing process at 80˚C and 65% relative humidity for 240 hours which is an equivalent to 50 years of natural ageing [10].

## 2.5. The exposure of wooden samples to basil oil

In tightly sealed glass containers wood samples, both chips and sawdust, were exposed to the vapors of basil oil, purchased from *Harraz* for Food Industry & National Products, for 5 consecutive days at normal room temperature, without vacuum. All samples were exposed to 2 $cm^3$ of distilled water mixed with Tween 80 (at the rate of 0.5%) and 3.0 mol./ml of basil oil, and the control sample (S1) was exposed to 2$cm^3$ of distilled water without the addition of oil so that all wood samples would be exposed to the same relative humidity in airtight 250-ml Erlenmeyer flasks.

To minimize error during the interpretation of both pH value and FTIR analysis, half of the previously aged sawdust samples, control (S1) and vapor treated (S2 and S3), were heat aged and given the codes ($S1^{80˚C}$, $S2^{80˚C}$, $S3^{80˚C}$).

## 2.6. Evaluation methods

### 2.6.1. Color measurements

Color measurement was carried out at the Conservation Department - Faculty of Archaeology - Cairo University, using the CIE lab system, *Miniscan EZ - Hunter Lab - Mesz0693*. In the case of color change measurements, two samples had to be used, because of extreme variation in wood color within the same woodblock; and due to the fact that sycamore wood, like any other type of wood, is anisotropic, it was necessary to determine a specific area for color measurements in each sample before and after exposure to the oil vapors to obtain accurate results. For color change calculations the samples were measured before and after exposure to the essential oil, and after heat ageing in the same area to provide consistency during measurements. Three replicates were used for each sample to evaluate color measurements [10] [11].

### 2.6.2. The pH value

The pH value of wood was measured with a pH/ MV & Temperature Meter, AD 1030. Two grams of sawdust were mixed with 40

$cm^3$ distilled water and the pH value was measured after 10 minutes' under lab conditions [12]. The measurement was repeated after 24 hours to confirm that the pH value did not change after longer periods of immersion in water.

### 2.6.3. Attenuated total reflectance/ Fourier Transform Infrared Spectroscopy

All the wood samples, mask and experimental samples, were analyzed using Fourier Transform Infrared Spectroscopy to study the chemical changes in both the archaeological sample and the experimental samples before and after exposure to the essential oil and to determine how the wood had been affected by the oil treatment before and after heat ageing. All wood samples were analyzed with a JASCO FTIR - 6100 type A, in the frequency range of 400-4000 $cm^{-1}$, using the KBr pellet technique in transmission mode at the National Institute for Standards (NRC) in Giza, Egypt and Essential FTIR software version (2.00.045 Infrared File Viewer).

## 3. Results and discussions

### 3.1. Mycological study

The mycological infestation of the mask proved that it had been infested with *Aspergillus spp.* (*A. niger* and *A. flavus*) [13][14], which was loaded by a total of 41.18%. This result confirmed that this type of wood is infested with *Aspergillus spp.*, and needs to be monitored and treated on a regular basis, without causing any chemical or physical alterations to the artifact (Table 1).

### 3.2. Color measurements

Results of color measurements (Table 2) revealed that basil oil had a moderate effect on wood color as there is no notable change in (ΔE) according to the CIE lab equation. ΔE of the control sample S1 was 1.96 after exposure to water only, S2 that had been treated with basil oil vapor gave a similar value, but ΔE value of S3 was slightly higher. With the value of ΔE lower than 2, there is no significant color change as in the case of the control sample and sample S2. A clear change in the value of both oil- treated samples is evident in the L and b values, yet remained almost stable in the a values. The most sensitive parameter of wood surface quality, namely (Δ**L**) [11], gave a negative value after treatment in samples S2 and S3 (-1.17, -2.99, respectively) indicating that a slight darkening occurred in the samples, but after ageing the value of (Δ**L**) changed to a positive value in $S1^{80^\circ C}$, $S2^{80^\circ C}$ and $S3^{80^\circ C}$ (8.79, 7.36 and 7.36, respectively) indicating that the wood surface became lighter. The (Δb) was much higher than the values before heat ageing, which explains the slight fading and yellowing of wood due to heat ageing [11] [15].

Color change of the wood surface after heat ageing occurred in all three samples $S1^{80^\circ C}$, $S2^{80^\circ C}$ and $S3^{80^\circ C}$, where ΔE was (13.28, 12.63 and 13.35, respectively), which indicates that the color change is not due to the basil oil treatment. As mentioned in previous literature this color change may have been caused by some changes in the chemical composition of wood such as the degradation of the amorphous carbohydrates and extractives modification, in other words, the formation of degradation products of hemicelluloses and extractives, or it could be attributed to deterioration of lignin during exposure to heat [16] [17] [18].

### 3.3. The pH value of wood

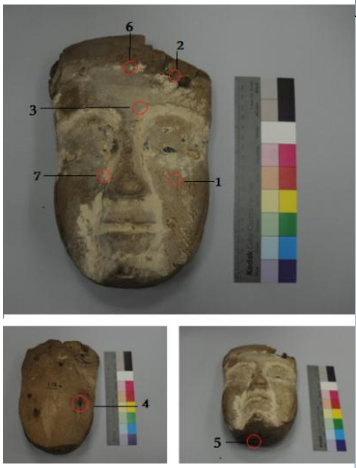
The pH value of wood before and after treatment revealed that basil oil, which has a pH value of 7.2, reduces the alkalinity of the sycamore wood. The control wood sample (S1) was 9.3, after exposure to the vapor the value of the wood sample (S2) decreased to (8.7). After thermal ageing the pH of the wood sample ($S1^{80^\circ C}$) decreased to (8.3), and the treated wood sample ($S2^{80^\circ C}$) that was exposed to thermal ageing had a pH value of (8.2), which indicates that the basil oil reduces the alkalinity of wood directly after treatment, and may have a slight effect on wood during thermal ageing.

The acidity of wood arises from the hydronium ions released chiefly by free and bound organic acids present in extractives and non-cellulosic polysaccharides [19]. It is not common that wood has an alkaline pH value, as in the case of sycamore wood, therefore it is very difficult to confirm that basil oil has an ability to reduce or change the pH value of different types of wood.

The low polysaccharide and extractives content (39 and 2 %, respectively) of sycamore wood [2], may explain its initial alkalinity, that gradually changed when exposed to basil oil and thermal ageing. It may be necessary to measure in future the pH of wood treated with basil oil on a weekly or monthly basis over a long period of time before finding a logic explanation for the effect of essential oils on wood.

**Table 1. Number of Aspergilli colonies recovered from the seven swab samples taken from different parts of the wooden face mask.**

| Swabs | Total colony no. | Aspergilli no. | Percent of Aspergilli | Species |
|---|---|---|---|---|
| 1 | 4 | 4 | 23.52% | *A. niger* |
| 2 | 6 | 1 | 5.88% | *A. flavus* |
| 3 | 1 | - | 0 | - |
| 4 | 2 | - | 0 | - |
| 5 | 5 | 2 | *11.78%* | *A. niger* |
| 6 | - | - | 0 | - |
| 7 | 2 | - | 0 | - |



The wooden mask under study, with the 7 areas that were chosen for swab sampling.

**Table 2. Color change measurements.**

| Sample | L | ΔL | Δb | Δa | ΔE |
|---|---|---|---|---|---|
| **Before and after exposure to the vapor** | | | | | |
| **S1** | **48.93** | **-0.98** | **1.47** | **0.87** | **1.96** |
| **S2** | **48.08** | **-1.17** | **1.15** | **0.88** | **1.86** |
| **S3** | **47.54** | **-2.99** | **1.59** | **1** | **3.53** |
| **All samples after heat ageing** | | | | | |
| **S1$^{80^\circ C}$** | **57.72** | **8.79** | **9.92** | **0.94** | **13.28** |
| **S2$^{80^\circ C}$** | **56.16** | **7.36** | **10.21** | **1.08** | **12.63** |
| **S3$^{80^\circ C}$** | **56.51** | **7.36** | **9.81** | **1.25** | **13.35** |

**S1: control sample, S2, S3: samples exposed to oil vapor, S1$^{80^\circ C}$, S2$^{80^\circ C}$, S3$^{80^\circ C}$ samples after heat ageing.**

### 3.4. Fourier transform infrared spectroscopy of basil oil and wooden samples

Fourier transform infrared spectrum was used to identify and assess the stability of chemical constituents. Functional groups of the active components are based on the peaks obtained through stretching and bending vibrations in the region of infrared radiation in wooden samples and basil oil as shown in Figures 1, 2 and 3 and Table 3 [20] [21].

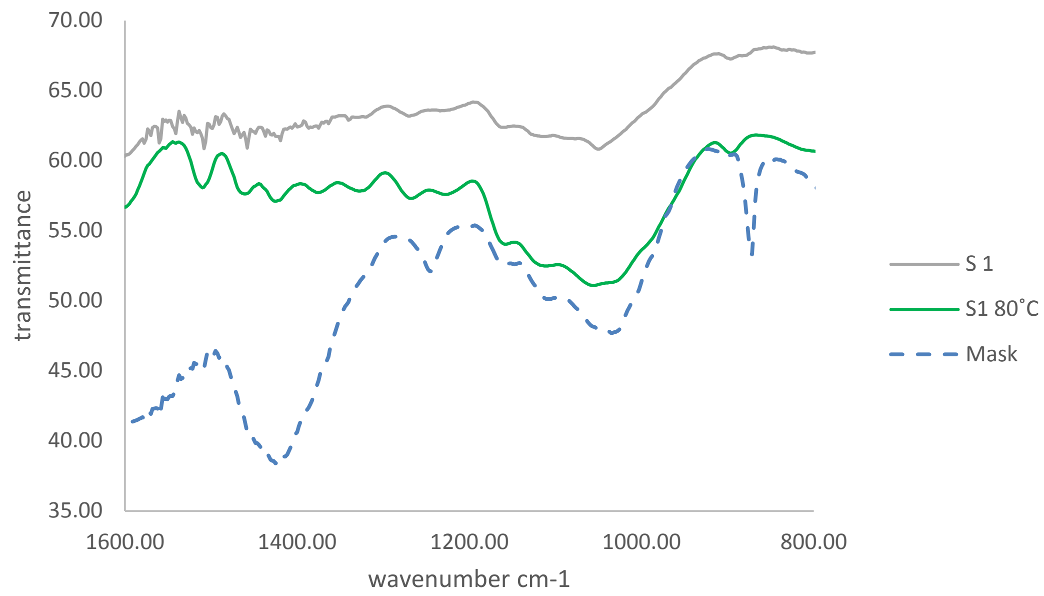



**Fig. 1. FTIR spectra of experimental wooden samples, S1: control sample, S1$^{80^\circ C}$ sample after heat ageing, and mask.**

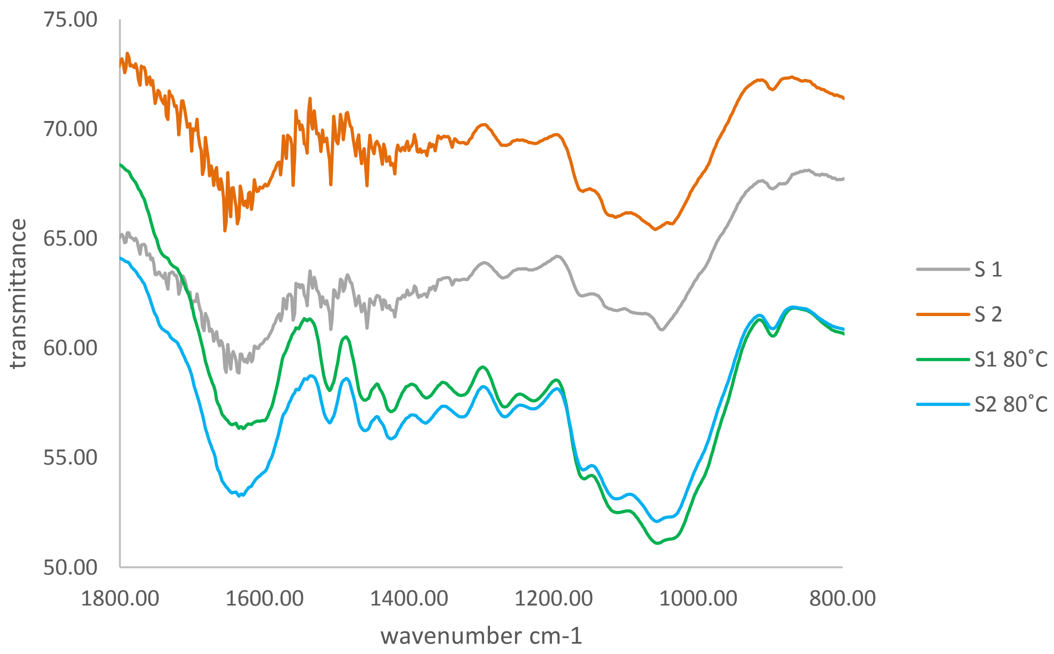



**Fig. 2. FTIR spectra of experimental wooden samples, S1: control sample, S2: sample exposed to oil vapor, S1$^{80^\circ C}$, S2$^{80^\circ C}$ samples after heat ageing**

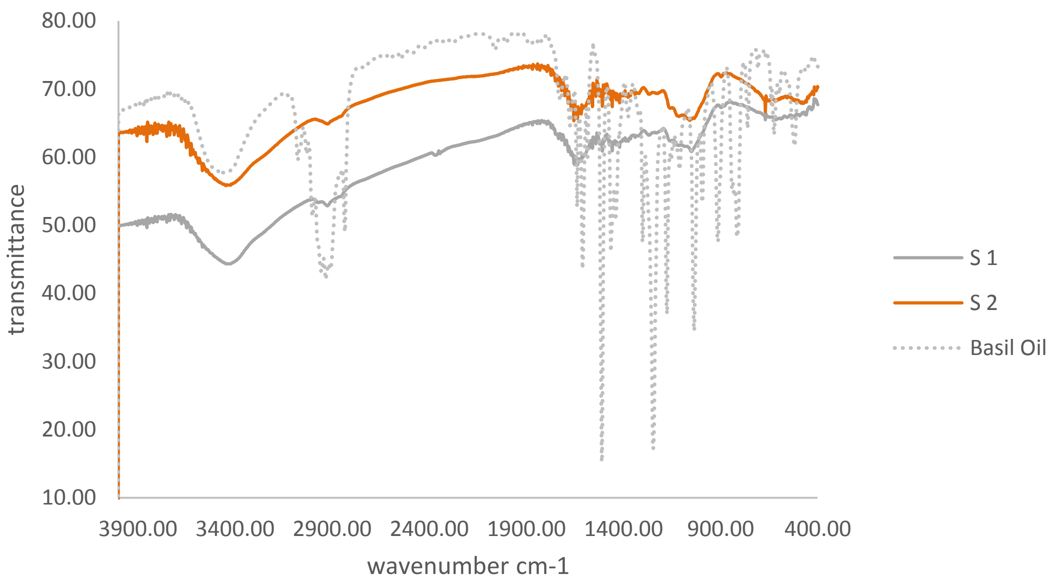



**Fig. 3. FTIR spectra of experimental wooden samples S1: control sample, S2: sample exposed to oil vapor, and basil oil**

By comparing the functional groups at specific wavenumbers of the samples (S1, S1$^{80°C}$, S2 and S2$^{80°C}$) it is clear that hemicellulose is very weak in the control sample (S1) and also in the treated sample (S2), and it disappeared in the aged control sample S1$^{80°C}$ and the aged treated sample S2$^{80°C}$, which is in agreeance with what was noted in previously published research that full weathering showed an initial growth of free carbonyl groups, followed by a decrease in intensity as these functional groups are leached out of the wood [22] [23] [24]. By comparing the spectra of the wood before and after heat ageing with the spectra of the mask it is clear that changes of intensities were mainly noticeable in the bands assigned to cellulose (Fig.1), and the same changes also occurred in sample S2$^{80°C}$ (Fig.2). This is a clear indication that heat has a very strong effect on wood components, and if it had not been for the fungal infestation of the mask, presumably a stronger similarity between the spectra of the mask and heat aged wood would have been noted.

The peaks for cellulose (crystallized and amorphous) of the four samples (S1, S1$^{80°C}$, S2 and S2$^{80°C}$) at around 1425 cm$^{-1}$, are sharp in S1 and S2 at 1417 cm$^{-1}$ and 1419 cm$^{-1}$, respectively, but after ageing a broadening of the peak occurred in S1$^{80°C}$ and in S2$^{80°C}$ at 1417 cm$^{-1}$.

The bands at 1375 cm$^{-1}$ refer to CH bending of amorphous cellulose, in S1 and S2 a weak sharp peak is found at 1373 cm$^{-1}$, but after heat ageing there is a broad peak at 1365 in S1$^{80°C}$ and at 1371 cm$^{-1}$ in S2$^{80°C}$.

OH bending in sample S1 is in the form of a very weak sharp peak at 1334 cm$^{-1}$; in S2 it is a weak sharp peak at 1336 cm$^{-1}$ but in both S1$^{80°C}$ and S2$^{80°C}$ a broadening of the peak occurred at 1321 cm$^{-1}$.

The peak of C-O-C asym, bridge oxygen stretching cellulose is weak in both samples S1 and S2 at 1153 cm$^{-1}$ and 1160 cm$^{-1}$, respectively; but after heat ageing the peak broadened in samples S1$^{80°C}$ and S2$^{80°C}$ at 1149 cm$^{-1}$ and 1159 cm$^{-1}$, respectively.

The band at 897 cm$^{-1}$, which refers to asym. out of phase ring stretching cellulose in sample S1 is sharp and weak at 889 cm$^{-1}$ and in S2 it is weak and broad at 891 cm$^{-1}$;

**Table 3. FTIR bands of wooden samples and basil oil**

| Basil Oil | | | Mask | S 1 | S1 $^{80\ C}$ | S 2 | S2 $^{80\ C}$ |
|---|---|---|---|---|---|---|---|
| Bands assigned to Oil [25] | | Bands assigned to Hemicellulose and Cellulose in Wood | | | | | |
| Bending vibration of N-H amino acids, C=O stretching of aldehyde, ketons and ester. | 1718 cm$^{-1}$ | 1735 C=O stretching in unconjugated ketones | 1733 cm$^{-1}$ | 1733 cm$^{-1}$ | --- | 1733 cm$^{-1}$ | --- |
| | weak sharp peak | | v. weak and sharp | v. weak and sharp | Absent | v. weak | Absent |
| Stretching vibrations of C-O amide and of C-C stretching from the phenyl groups | 1438 cm$^{-1}$ | 1425 cm$^{-1}$ $CH_2$ bending Cellulose (crystallised I and amorphous) | 1418 cm$^{-1}$ | 1417 cm$^{-1}$ | 1417 cm$^{-1}$ | 1419 cm$^{-1}$ | 1417 cm$^{-1}$ |
| | Sharp | | strong and broad | sharp peak and weak | broad peak | V .weak and sharp | V .weak and broad peak |
| Stretching vibrations of C-O amide and of C-C stretching from the phenyl groups. | 1373 cm$^{-1}$ | 1375 cm$^{-1}$ CH bending Cellulose | --- | 1373 cm$^{-1}$ | 1365 cm$^{-1}$ | 1373 cm$^{-1}$ | 1371 cm$^{-1}$ |
| | sharp | | Absent | Weak, sharp peak | broad peak | V. weak, sharp peak | V. weak and broad peak |
| ------ | | 1336 cm$^{-1}$OH in plane bending Cellulose (amorphous) | --- | 1334 cm$^{-1}$ | 1321 cm$^{-1}$ | 1336 cm$^{-1}$ | 1321 cm$^{-1}$ |
| | | | Absent | Weak, sharp peak | broad peak | V. weak, sharp peak | V. weak and broad peak |
| ------ | | 1317 $CH_2$ wagging Cellulose (crystallised I) | --- | 1313 cm$^{-1}$ | --- | --- | --- |
| | | | Absent | V. weak | Absent | Absent | Absent |
| stretching vibrations of carbonyl C-O, or O-H bending | 1176 cm$^{-1}$ | 1163 cm$^{-1}$COC asym. bridge oxygen stretching Cellulose | 1162 cm$^{-1}$ | 1153 cm$^{-1}$ | 1149 cm$^{-1}$ | 1160 cm$^{-1}$ | 1159 cm$^{-1}$ |
| | sharp peak | | v.v. weak and broad | V. weak and sharp | Broad | V. weak and broad | V. broad and weak |
| below 1000 cm$^{-1}$ corresponds to C-H bending vibrations | 912 cm$^{-1}$ | 897 cm$^{-1}$asym. Out of phase ring stretching Cellulose | 874 cm$^{-1}$ | 889 cm$^{-1}$ | 889 cm$^{-1}$ | 891 | 890 |
| | sharp peak | | Strong and sharp | V. weak and sharp | Broad | V. weak and broad | V. weak and broad |
| N-H bending vibrations and aromatic domain | 1583 cm$^{-1}$ | Bands assigned to Lignin in Wood | | | | | |
| | | 1594-1602 cm$^{-1}$ conjugated C–O | --- | --- | --- | --- | --- |
| | sharp | | Absent | Absent | Absent | absent | absent |
| N-H bending vibrations and aromatic domain | 1510 cm$^{-1}$ | 1505-1511 cm$^{-1}$ for C=C stretching vibration in lignin aromatic skeletal | 1508 cm$^{-1}$ | 1508 cm$^{-1}$ | 1506 cm$^{-1}$ | 1508 cm$^{-1}$ | 1506 cm$^{-1}$ |
| | V. strong sharp peak | | v. v weak and sharp | sharp peak | broad peak | sharp peak | broad peak |
| stretching vibrations of carbonyl C-O, or O-H bending | 1245 cm$^{-1}$ | 1264-1270 cm$^{-1}$ cm$^{-1}$ for guaiacyl ring breathing, C–O stretch in lignin | 1247 cm$^{-1}$ | 1259 cm$^{-1}$ | 1257 cm$^{-1}$ | 1263 cm$^{-1}$ | 1263 cm$^{-1}$ |
| | Sharp | | Sharp peak | Weak and broad | Broad | Weak and broad | Weak and v. broad |

but after ageing a broad and weak band was recorded at 889 and 890 cm$^{-1}$ in S1$^{80°C}$ and S2$^{80°C}$, respectively.

The bands of conjugated C-O from 1594-1602 cm$^{-1}$ was not recorded in any of the samples before and after treatment and ageing.

C=C stretching vibration in lignin aromatic skeletal is sharp in samples (S1 and S2) at 1508 cm$^{-1}$, but after heat ageing the bands shifted to 1506 cm$^{-1}$ in (S1$^{80°C}$ and S2$^{80°C}$) and broadened.

Conjugated C–O in lignin at 1594-1602 cm$^{-1}$ was absent in all samples (mask and experimental samples), which is in agreeance with previously published results [26]. C-O stretching in lignin (guaiacyl) is weak in sample S1 and S2 at 1259 and 1263 cm$^{-1}$, respectively, and broadened after exposure to heat ageing in sample S1$^{80°C}$ and S2$^{80°C}$ at 1257 and 1263 cm$^{-1}$, respectively.

The main bands that are assigned to the wood carbohydrates and lignin that have the same wavenumber as basil oil became broader after exposure to the oil vapor, and remained so after heat ageing.

Comparison of intensity ratio of lignin and carbohydrates in any wood sample can help explain the chemical changes within a sample, using a very small amount of the sample, as previously mentioned in literature [23]. Lignin, hemicellulose, amorphous and crystallized cellulose are each affected in a different manner when exposed to the same treatment or ageing conditions. In the above mentioned samples, the wood, with a pH of 9.3, was exposed to the vapor of basil oil, which has a pH of 7.2. This treatment changed the pH of wood to 8.7, making the wood less alkaline. The exposure of wood, before and after treatment, led to a further decrease of the wood alkalinity. These changes are reflected in the color change of the samples, especially after heat ageing. To better understand and correlate the obtained results, the intensities in the FTIR spectra were compared (Table 4) and explained as follows:

The ratio of intensities in the FTIR spectra of the control sample (S1) and the sample treated with basil oil (S2) indicated that there was a slight decrease in the ratio lignin/hemicellulose and lignin/amorphous cellulose bands at 1375 cm$^{-1}$ in the sample which was exposed to the vapor of basil oil. A strong decrease of ratio between lignin/crystallized cellulose at 1425 cm$^{-1}$ was recorded in the same sample, yet a very high increase in ratio was recorded between lignin/895 cm$^{-1}$.

After exposing untreated and treated wood (S1$^{80°C}$ and S2$^{80°C}$, respectively) to heat ageing, hemicellulose totally disappeared. By comparing the heat aged sample (S1$^{80°C}$) with the control sample (S1), and the sample after treatment and ageing (S2$^{80°C}$) with the treated sample (S2), a very strong decrease of ratio between lignin/crystallized cellulose at 1425 cm$^{-1}$ was calculated. The ratio between lignin/amorphous cellulose bands at 1375 cm$^{-1}$ also decreased, yet a surprisingly high increase was calculated between lignin/895 cm$^{-1}$ in sample S1$^{80°C}$, on contrary to the sample S2$^{80°C}$, in which the ratio decreased. This can be correlated with the lighter color of wood in the results obtained from the color measurements.

The heat ageing process had a negative effect on the 897 asym. out of phase ring stretching in cellulose, after the exposure to the oil vapor the band intensity increased, and then decreased again reaching almost the same ratio as in the control sample.

By comparing the ratio between lignin and carbohydrates in the four samples (S1, S1$^{80°C}$, S2, S2$^{80°C}$), it is clear that the heat ageing had a far stronger degrading effect on the wood than the exposure of wood to basil oil vapors, which was also noted in the aforementioned color change measurements.

## 4. Conclusion

In previously published research, basil oil has proven its effectiveness in inhibiting fungal infection in wood in general and against *Aspergillus* spp. in particular. The results obtained in this study indicate that basil oil did not have a negative effect on the chemical composition of the sycamore wood and the change was caused by the ageing process. The recorded changes in color values (L, a, and b) and total color difference (ΔE) were so small; and this may be due to the heterogeneity of wood samples and/or the

**Table (4) Ratio of lignin and carbohydrate intensities**

| L | S1 | Result | S2 | Result |
|---|---|---|---|---|
| L/ 1735 | (2.1/0.73) | 2.87 | (2.62/1.23) | 2.13 |
| L/1425 | (2.1/0.12) | 17.5 | (2.62/0.29) | 9.03 |
| L/1375 | (2.1/0.2) | 10.5 | (2.62/0.28) | 9.35 |
| L/895 | (2.1/0.36) | 5.83 | (2.62/0.24) | 10.9 |
| L | S1$^{80°C}$ | Result | S2$^{80°C}$ | Result |
| L/ 1735 | (2.65/--) | --- | (2.05/--) | --- |
| L/1425 | (2.65/0.74) | 3.58 | (2.05/0.93) | 2.2 |
| L/1375 | (2.65/0.36) | 7.36 | (2.05/ 0.44) | 4.65 |
| L/895 | (2.65/0.22) | 12 | (2.05/ 0.37) | 5.5 |

minute amount of absorbed oil, which could not be detected in the FTIR spectra.

The results of this experimental study indicated that the oil has a very mild effect on the chemical and physical properties of wood, and even contributed in minimizing the effect of heat ageing on wood and there may be a probability that basil oil slightly protects wood from damage during exposure to the ageing process. This is in agreeance with previous results which recorded that nontoxic vegetable oils can form a protective layer on the surface of wood cells, due to the decrease of the water uptake of wood [27]. Another paper indicated that the compression strength values of samples treated with vegetable oils were higher than the values of untreated samples after weathering exposure [11].

Currently a lot of researchers are discussing the use of essential oils in different disciplines and application methodologies; and it is worthy to note that a lot of points still need to be evaluated, before attempting to use these environmentally friendly materials in conservation science. It is of major importance to focus in future research on identifying the different components of basil oil, because of the extremely large variety of the chemical composition and antioxidant activity of the essential oils and extracts of sweet basil, such as the results of an investigation that demonstrated significant variations in the antioxidant activities of sweet basil essential oils and extracts from three areas in Upper Egypt [28]. The variation of basil oil components or any other essential oil will not only differ in its effectiveness in inhibiting fungal infestation, but it will also have different effects in the treatment of wood species used in historical and archaeological artifacts.

## References


1. S. A. M. Hamed, and N. M. N. El Hadidi, “The Use of SEM-EDX Investigations in estimating the penetration depth of preparation layers within wood structure”, Advanced Research in Conservation Science, vol. 1, no. 1, 2020, pp. 1-15
2. N. M. N. El Hadidi, “A Study on some physical, mechanical and chemical changes of deteriorated archaeological wood and its consolidation, with the application on some selected artifacts at the Islamic museum of the Faculty of Archaeology”. PhD thesis. [in Arabic, unpublished], Faculty of Archaeology: Cairo University, 2003.
3. N. M. N. El Hadidi, “Changing Research Trends in the field of Archaeological Wood at the Conservation Department - Faculty of Archaeology – Cairo University”, Studies in Conservation, vol. 60, no. 3, 2015, pp. 143-154
4. N. M. N, El Hadidi, S. S, Darwish, “Chemical Changes of Archaeological Wood”, in Chem.05 – Faculty of Science; Cairo University, 2008, NA.
5. S. S. Darwish, N. M. N. El Hadidi, M. Mansour. “The Effect of Fungal Decay on Ficus sycomorus Wood”, International Journal of Conservation Science Vol. 4 No. 3, 2013, pp. 271-282
6. A. A. Mokbel and A. A. Alharabi. “Antifungal effects of basil and camphor essen-

tial oils against Aspergillus flavus and A. parasiticus", Australian Journal of Crop Science, Vol. 9, 2015, pp.532-537.

7. A. Piyo, J. Udomsilp, P. Khang-Khun, P. Thobunluepop "Antifungal activity of essential oils from basil (Ocimum basilicum Linn.) and sweet fennel (Ocimum gratissimum Linn.): Alternative strategies to control pathogenic fungi in organic rice "Asian Journal of Food and Agro-Industry, Special Issue, 2009, S2-S9. www.ajofai.info.
8. M. Zyani, D. Mortabit, S. El Abed, A. Remmal, S. I. Koraichi "Antifungal activity of five plant essential oils against wood decay fungi isolated from an old house at the Medina of Fez" International Research Journal of Microbiology Vol. 2., No. 3, 2011, pp.104-108.
9. Y. Zidan, N. M. N. El Hadidi, M. Fawzy, "Examination and analyses of a wooden face at the museum storage at the Faculty of Archaeology, Cairo University," Mediterranean Archaeology & Archaeometry, Vol. 16, 2016, pp. 1-11.
10. M. Fawzy, "A Comparative Study on the Effect of Cleaning Materials on the Chemical Composition and Mechanical Properties of Damaged and Undamaged Wood with the Application on Chosen Archaeological Wood" PhD Thesis (in Arabic unpublished): Conservation Department, Faculty of Archaeology, Cairo University, 2016.
11. O. Ozgen, O.T. Okan, U.C. Yildiz, I. Deniz, "Wood surface protection against artificial Weathering with vegetable seed oils" BioResources, Vol. 8, No. 4, 2013, pp. 6242-6262.
12. A. Geffert, J. Geffertova, M. Dudiak, "Direct Method of Measuring the pH Value of Wood", Forests, Vol. 10, 2019, pp.1-9. www.mdpi.com/journal/forests. doi:10.3390/f10100852.
13. K. H. Domsch, W. Gams and T. H. Anderson, "Compendium of Soil Fungi" Academic Press (London, UK) Ltd., Vol.1, 1980.
14. R. A. Samson, C. M. Visagie, J. Houbraken, S. B. Hong, V. Hubka, C. H. W. Klaassen, G. Perrone, K.A. Seifert, A. Susca, J.B. Tanney, J. Varga, S. Kocsubé, G. Szigeti, T. Yaguchi, J.C. Frisvad, "Phylogeny, identification and nomenclature of the genus Aspergillus", Studies in Mycology, Vol. 78, 2014, pp. 141-173. doi:10.1016/j.simyco.2014.07.004.
15. S. Barsik, M. Gasparik, E, Y, Razumov, "Effect of thermal modification on the colour changes of oak wood". Wood Research, Vol.60, No.3, 2015, pp. 385-396.
16. V. Kamperidou, I., Barboutis, V., Vasileiou, "Response of colour and hygroscopic properties of Scots pine wood to thermal treatment", Journal of Forestry Research, Vol. 24, No.3, 2013, pp. 571-575.
17. R. Cividini, L., Travan, O., Allegretti, "White beech: A tricky problem in drying process", In: Proceeding of 7th International Scientific Conference on Hardwood Processing (ISCHP) Quebec City, Canada, 2007. pp. 135-140.
18. C. Brischke, C., Welzbacher, K., Brandt, A., Rapp, "Quality control of thermally modified timber: Interrelationship between heat treatment intensities and CIE L*a*b* colour data on homogenized wood samples. Holzforschung, Vol. 61, No.1, 2007, pp. 19-22.
19. M. Balaban and G. Uçar, "The correlation of wood acidity to its solubility in hot water and alkali", Holz als Roh- und Werkstoff, vol. 59, 2001, pp. 67-70
20. A. S. Frank, "Infrared Spectroscopy". In: Handbook of Instrumental Tech-

niques for Analytical Chemistry, 1st ed.; Sherman, H.; Prentice Hall PTR, New Jersey,1997

21. D. Predoi, A. Groza, S. L. Iconario, G. Predoi, F. Barbuceanu, R. Guegan, M.S. Motelica-Heino, "Properties of Basil and Lavender Essential Oils Adsorbed on the Surface of Hydroxyapatite", Materials, Vol 11, 2018, pp. 1-17
22. E.L. Anderson, Z. Pawlak, N.L. Owen, W.C. Feist, "Infrared Studies of Wood Weathering. Part I: Softwoods", Applied Spectroscopy, Vol. 45, No. 4, 1991, pp. 641-647.
23. N. M. N. El Hadidi, "Decay of softwood in archaeological wooden artifacts", Studies in Conservation, Vol. 62, No. 2, 2017, pp. 83-95.
24. N. M. N. El Hadidi, H. Abdel-Monem, M. Fawzy, G. G. Hashem, "Retreatment and conservation of a wooden panel previously treated with bees wax", Advanced Research in Conservation Science, vol. 1, no. 2, DOI: 10.21608/ARCS.2020.33541.1006, 2020, pp. 48-65
25. M. Krishnaveni, J. S. Kumar, "FTIR, GC-MS/MS Analysis of Essential Oil from Coriandrum sativum Seeds, Antibacterial Assay", Advances in Bioresearch, Vol. 7, No. 5, 2016, pp. 124-129.
26. N. M. N. El Hadidi, S. A. M. Hamed, "The effect of Preparation layers on the Anatomical Structure and Chemical Composition of Native Egyptian Wood", In: A. Amenta, and H. Guichard, (eds.), Proceedings First Vatican Coffin Conference, Vatican Museums Conference Hall, 19 - 22 June 2013, Vol. I, Edizioni Musei Vaticani, 2017, pp. 199-210
27. D. E. Tomak, U.C. Yilidiz, "Applicability of vegetable oils as a wood preservative" Artvin Coruh University Faculty of Forestry Journal, Vol 13, 2012, pp.142-157.
28. A. F. Ahmed, F. A.K. Attia, Z. Liu, C. Li, J. Wei, W. Kang, "Antioxidant activity and total phenolic content of essential oils and extracts of sweet basil (Ocimum basilicum L.) plants", Food Science and Human Wellness, Vol. 8, 2019, pp. 299-305.